Energy Mines and Resources Canada | Energie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

ATTENUATION MEASUREMENT OF EAR MUFFS AT FALCONBRIDGE COMPLEX: NO. 5 SHAFT, THE EAST MINE, AND THE MILL AND SMELTER, 1984

M.U. SAVICH AND J.K. WEGLO

ELLIOT LAKE LABORATORY

JANUARY 1986

This document is an unedited internal report prepared primarily for [illegible] and [illegible] purposes. It does not represent the official opinion of the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport [illegible] rédigé [illegible] pour fins de diffusion et de documentation [illegible] ne représente nullement l'opinion définitive du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

28 pp

MINERAL AND ENERGY TECHNOLOGY
MINING RESEARCH LABORATORIES
DIVISION REPORT M&ET/MRL 86-58 (TR)

MICROMEDIA
AUG 18 1986

ATTENUATION MEASUREMENT OF EAR MUFFS AT FALCONBRIDGE COMPLEX: NO. 5 SHAFT, THE EAST MINE, AND THE MILL AND SMELTER, 1984

by

M.U. Savich* and J.K. Weglo**

ABSTRACT

Ear muffs are the main protection of the mining workforce for the attenuation of noise.

The measurment of head size as against clamping force as well as the condition of the ear muffs are demonstrated as important variables in this attenuation of noise.

The "NO NOISE" ear muffs attenuation was about 10 dBA average with a standard deviation of 4.1 to 5.6 dBA at the Falconbridge Complex.

The Mark V ear muffs replacing those in this study, based on clamping force measurements versus head size can be expected to produce attenuation of less than 14 dBA.

*Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario.
** Director, Environmental Control, Falconbridge Ltd., Falconbridge, Ontario.

MESURE DE L'EFFICACITÉ DES CASQUES ANTIBRUIT À ATTÉNUER LE BRUIT AU COMPLEXE FALCONBRIDGE: AU PUITS N° 5, À LA MINE EST, AU MOULIN ET À LA FONDRIE, 1984

par

M.U. Savich* et J.K. Weglo**

RÉSUMÉ

Les casques antibruit sont la principale source de protection contre le bruit pour les travailleurs miniers.

La mesure de la taille de la tête par rapport à la force de serrage ainsi que l'état des casques antibruit sont indiqués comme étant d'importantes variables de l'atténuation du bruit.

Lors de l'étude au Complexe Falconbridge, le niveau d'atténuation du bruit "NO NOISE" des casques antibruit était en moyenne d'environ 10 dBA avec un écart type de 4,1 à 5,6 dBA.

Cependant, d'après les mesures de la force de serrage par rapport à celles de la taille de la tête, les casques antibruit Mark V qui ont remplacé les casques utilisés dans cette étude pourraient assurer une atténuation du bruit de moins de 14 dBA.

---

*Chercheur scientifique, Laboratoire d'Elliot Lake, CANMET, Énergie, Mines et Ressources Canada, Elliot Lake (Ontario).

**Directeur, Contrôle environnemental, Falconbridge Ltd., Falconbridge (Ontario).

CONTENTS

	Page
ABSTRACT	i
RESUME	ii
INTRODUCTION	1
MEASUREMENTS AND RESULTS	1
Head Size and Clamping Force	3
Condition of Ear Muffs	10
Attenuation Measurements	10
Mark IV Muffs	11
Ear Muff Comfort	12
CONCLUSIONS	13
ACKNOWLEDGEMENTS	14
REFERENCES	14
APPENDIX A	A-15
APPENDIX B	B-16
APPENDIX C	C-17
APPENDIX D	D-19
APPENDIX E	E-20
APPENDIX F	F-21
APPENDIX G	G-22

FIGURES

No.		
1.	The normal curve is known as mesokurtic while the more peaked curve is called leptokurtic, and the symmetrical frequency curve or bell-shaped curve of head size tests	5
2.	The clamping force frequency curve has positive skewness, but it also has two maxima	6
3.	Relationships between head size and clamping force at the Falconbridge Mine	8
4.	Standard deviation ellipse of "NO NOISE" muffs at Falconbridge Mine	9

TABLES

1.	Attenuation characteristics of ear muffs acquired for testing.	2

No.		Page
2.	Summary results of head size and clamping force tests	4
3.	Tests of ear muff conditions in mines and mills	10
4.	Comfort of ear muffs in mines and mills	12

INTRODUCTION

As part of the program of reducing noise, measurements were taken at all Falconbridge Mines and the ear muffs used there were tested for efficiency.

At Falconbridge Mine the following ear muffs were tested:

1) "NO NOISE", model NN3-F, the Hellberg Standard Volume Hearing Protector, hard hat attachment;
2) Mark IV, MSA, worn behind the head;
3) Mark V, Ear Cup Kit, MSA, hard hat attachment;
4) Peltor H7P3e, hard hat attachment; and
5) Bilsom Viking Muff 2314, hard hat attachment.

Testing was mostly done on "NO NOISE" ear muffs, model NN3-F, because 95% of the workforce used this model. Means and methods of testing, and theoretical and practical considerations of data, are described in the main report, and should be read to compare the Falconbridge Complex with other mines.

The latter three muffs have only recently begun to be used at the mine. On the Mark V Ear Cup Kit only head size and clamping force were tested.

Attenuation characteristics of the ear muffs as supplied by the manufacturer using the ANSI protocol (reference) are given in Table 1. From Noise Reduction Rating (NRR) data also supplied by the manufacturer, it can be concluded that all ear muffs provide relatively equal attenuation.

MEASUREMENTS AND RESULTS

It was not possible to complete a substantial number of tests because of a small number of work places. Instruments were greatly affected by the moisture in the mines, which accounted for most of the malfunctions we had. One microphone was outside the ear muff, and one was between the cup and the subjects ear. Brüel and Kjaer (B and K) dosimeters do not indicate readings greater than

Table 1 - Attenuation characteristics of ear muffs acquired for testing ANSI S.319-1874.

No.	Ear Muff	Characteristic	Frequency Hz									NRR
			125	250	500	1000	2000	3150	4000	6300	8000	
1	"NO NOISE" Model NN3-F, Hellberg	Mean	16.2	19.9	25.2	34.1	36.0	39.2	39.0	40.3	38.1	24
		Std. Dev.	2.5	1.8	2.0	1.7	2.2	3.1	2.0	4.0	4.1	
2	Mark IV, MSA	Mean	17.0	18.0	29.0	36.0	38.0	44.0	44.0	43.0	43.0	24
		Std. Dev.	2.6	2.6	3.1	3.2	4.1	7.2	4.6	4.7	5.7	
3	Mark V Ear Cup Kit MSA	Mean	14.9	20.2	28.2	35.0	33.4	35.4	33.5	33.1	32.2	24
		Std. Dev.	2.6	1.5	1.9	2.5	2.1	2.8	2.6	2.7	3.0	
4	Peltor H7P3e	Mean	14.1	18.8	28.1	36.2	35.6	38.4	35.0	35.5	36.4	24
		Std. Dev.	2.1	2.0	3.0	2.1	2.2	2.3	2.1	2.1	2.4	
5	Viking Muff No. 2314 Bilsom	Mean	15.0	21.0	27.0	37.0	36.0	38.0	42.0	42.0	39.0	25
		Std. Dev.	1.8	2.0	2.5	2.8	1.5	2.3	3.0	3.7	3.6	

115 dBA or less than 89 dBA. For this reason, it was often impossible to obtain the exact ear muff attenuation. Both instruments were either OSHA (doubling at 5 dB), or ISO (doubling at 3 dB), monitoring noise levels simultaneously. Sound level tests with the hand-held instruments took longer to complete. Head size was measured with outside calipers, and clamping force with a manual balance.

HEAD SIZE AND CLAMPING FORCE

Head size and clamping force tests were carried out on five different ear muffs using different populations. The results can be found in Appendices A and B, and the summary results in Table 2.

From Table 2 it is clear that clamping force was weakest on the first two ear muff types, which had been in use for a long time. The Institute of Occupational Medicine (IOM) in the United Kingdom is carrying out extensive research on hearing protectors for the National Coal Board, and the European Community has found that a typical muff, after three months use in a mine, provides only a quarter of the protection of a brand new muff (1). This was largely because of a reduction in the force exerted by the head band. From Table 2, the last two types of ear muffs were used by too small a population to allow evaluation.

Constructed normal frequency curves of a population of 34 (clamping force tests) have a mesokurtic shape; and those of a population of 46 (attenuation tests) have a bell-shaped curve (Figure 1). There are heads with a markedly small bizygomatic diameter, between 11.5 and 12.5 cm. The frequency curve for clamping force data has positive skewness (skewed to the right), with the large tail of distribution to the right (Figure 2). The low maximum occurs because of the markedly smaller heads surveyed here. From the diagram of population versus clamping force (Figure 2), it is clear that ear muff deterioration occurs along the entire interval from 400 (gwt) to 1500 (gwt). This is why we should not expect good attenuation of ear muffs. Bar graphs were constructed from the data

Table 2 - Summary results of head size and clamping force tests

No	Ear Muff	N*	Head Size (cm)		Clamp Force (gwt)		
			Mean	Std. Dev.	Mean	Std. Dev.	
1	"NO NOISE" Model NN3-F, Hellberg	39	14.14	0.54	990.44	322.22	Used long time
2	Mark IV, MSA	10	13.65	0.50	980.00	303.65	Used long time
3	Mark V, Ear Cup Kit, MSA	6	10.04	0.19	1170.83	128.86	Almost new
4	Peltor H7P3e	2	14.00	-	1300.00	-	Almost new
5	Viking Muff No. 2314, Bilsom	1	14.00	-	1350.00	-	Almost new
Σ(2-5)		19	14.01	0.53	1025.00	301.00	

Note: * Population

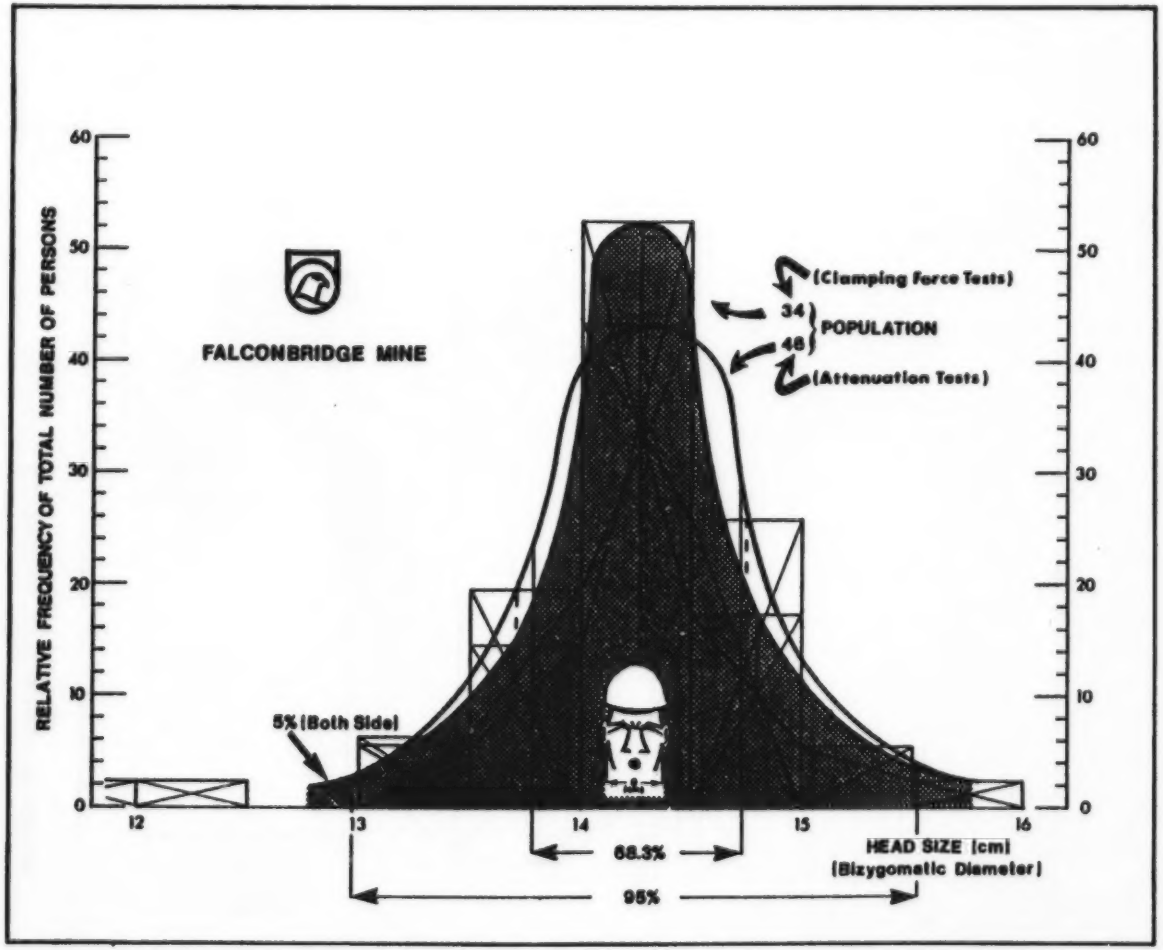


Fig. 1 - The normal curve is known as mesokurtic while the more peaked curve is called leptokurtic (population of 34), and the symmetrical frequency curve or bell-shaped curve (population of 46) of head size tests.

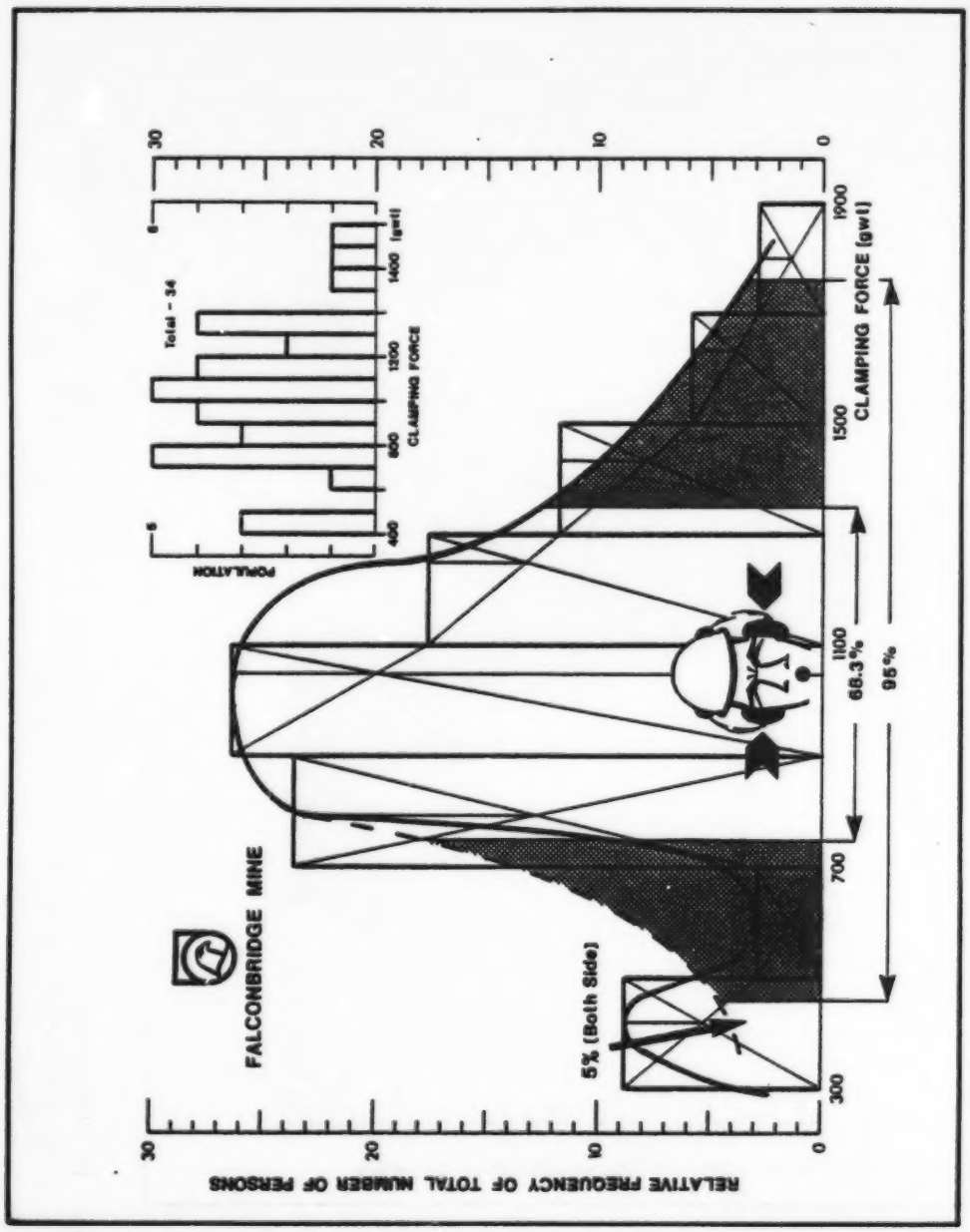


Fig. 2 - The clamping force frequency curve has positive skewness, but it also has two maxima.

on "NO NOISE" muffs for a population of 34 (Figure 3). It is obvious that clamping force is not in direct relationship with head size, due to ear muff deterioration. Data from Appendix A was used to construct a standard deviation (error) ellipse (Figure 4). In this construction it is evident that the ellipse does not cover the plotted field of clamping force versus head size, and therefore the attenuation would be expected to be low. The error ellipse yields a qualitative result from quantitive content.

In the mine at the 500 level with a Joy A.L. 60 jackleg six frequency analyses were performed, their averages being:

Frequency (Hz) in dB									dBA	dBC
31.5	63	125	50	500	1k	2k	4k	8k		
93.0	106.3	106.0	110.0	109.0	111.2	107.0	108.4	107.0	116.0	117.4

The following equation can be used to estimate the sound level (dBA) at a worker's ear when wearing a personal hearing protector:

$$dBA = dBC - (NRR - 10)$$

where dBC is the C-weighted sound level to which the worker is exposed, NRR is the Noise Reduction Rating of the protector, and 10 is a factor used to "derate" the NRR to conditions consistent with the "real world". Based on this equation the sound level at a jackleg driller's ear (in dBA), when working at a location where the sound level is 117.4 dBC and using a personal hearing protector rated at NRR = 24 would be 103.4 dBA. For a noise attenuation of 12.6 dBA. Further protection from noise pollution will be achieved by using ear plugs in conjunction with muffs. By measuring ear muff attenuation we can check the accuracy of the formula.

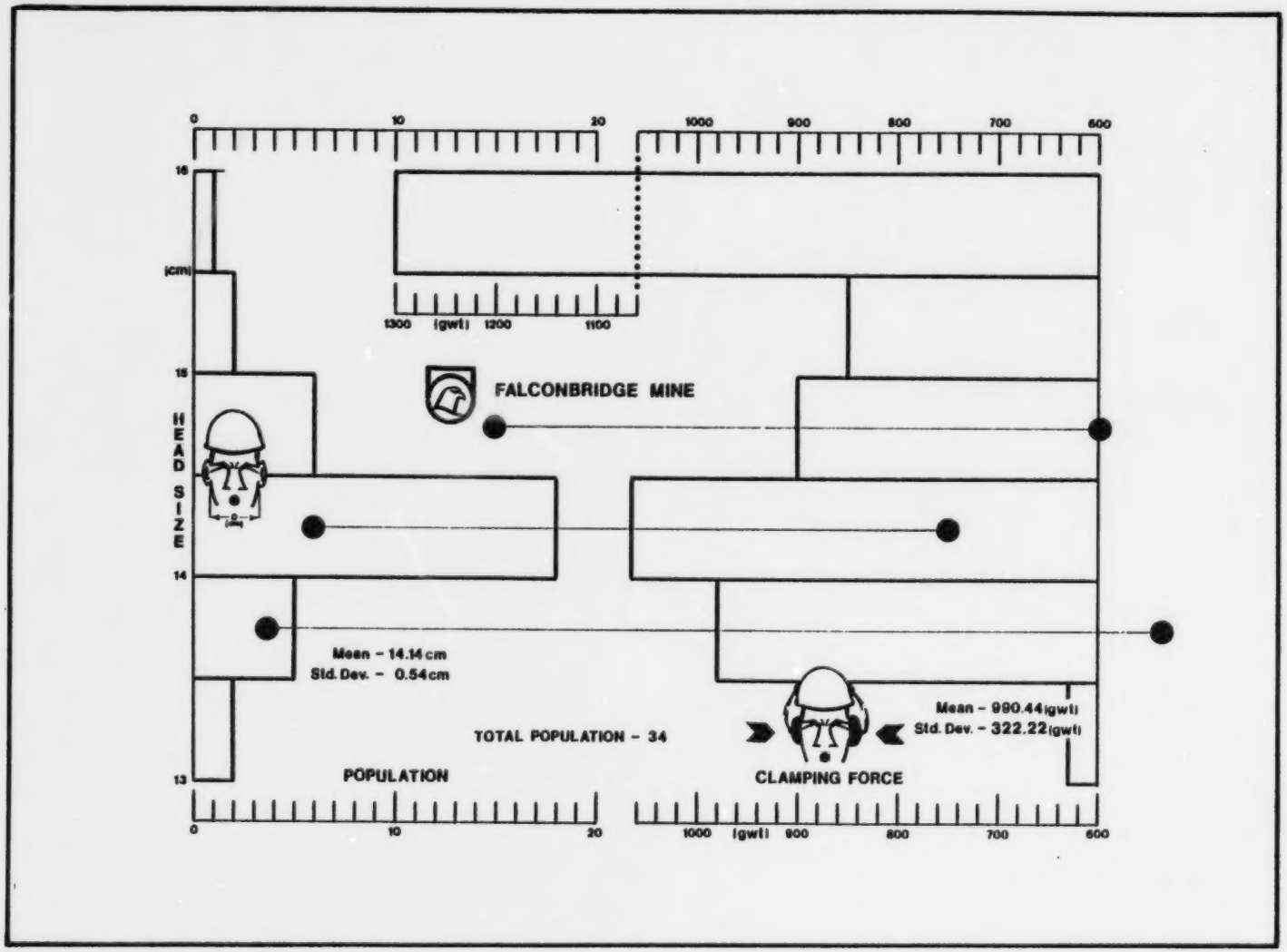


Fig. 3 - Relationships between head size and clamping force at the Falconbridge Mine.

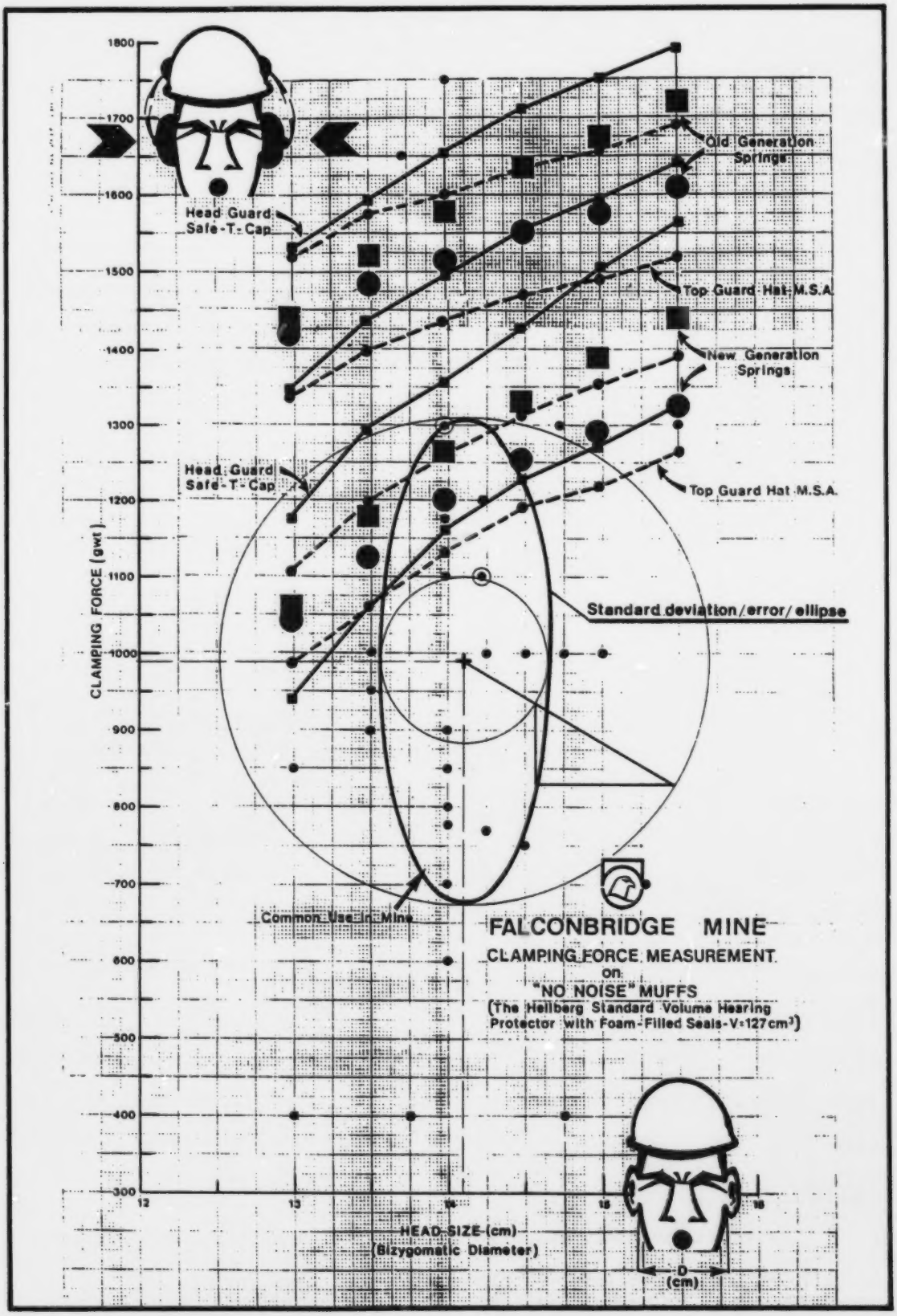


Fig. 4 - Standard deviation (error) ellipse of "NO NOISE" muffs at Falconbridge Mine.

CONDITION OF EAR MUFFS

The ear muffs were not in good condition (Table 3).

Table 3 - Tests of ear muff conditions in mines and mills

No.	Ear Muff	N*	Condition of Ear Muff					
			Good		Fair		Poor	
			N_1	Percent	N_2	Percent	N_3	Percent
1	"NO NOISE" (NN3-F)	34	23	67.65	8	23.53	3	8.82
2	Mark IV, MSA	10	2	20.00	7	70.00	1	10.00
3	Mark V Ear Cup Kit, MSA	6	6	100.00	0	0.00	0	0.00
4	Peltor H7P3e	2	2	100.00	0	0.00	0	0.00
5	Viking Muff No.2314, Bilsom	1	0	0.00	0	100.00	0	0.00
1-5	Σ	53	33	62.26	16	30.19	4	7.55

Note: *Population ($N^* = N_1 + N_2 + N_3$)

Workers had a tendency to bend the springs on "NO NOISE" ear muffs to make them more comfortable. This action caused the deterioration of ear muffs attenuation. The clamping force test will quantify the amount of deteriioration.

It should be noted that the Mark IV MSA ear muffs were in very poor shape and had been used for a long time. Shortly after these tests they were replaced. Other ear muff models were of more recent "vintage". This experience shows that, if anything, more care should be taken in the maintenance of ear muffs.

ATTENUATION MEASUREMENTS

Attentuation measurements were performed on the following ear muffs:

1) "NO NOISE" model NN3-F, 23 measurements (Appendix C);

2) Mark IV, MSA, 9 measurements (Appendix D);

3) Peltor H7P3e, 9 measurements (Appendix E);

4) Bilsom Viking Muff 2314, 5 measurements (Appendix F);

Testing was carried out on various types of equipment: Joy jacklegs and stopers, Gardner Denver jumbo drills, in-the-hole (ITH) drills, mucking machines, scooptrams, crushers, ball mills and smelter.

Tests of "NO NOISE" ear muffs show the following attenuations (Appendix C):

Characteristic	dBA	90% Conf. Limit	95% Conf. Limit
OSHA mode - Mean	9.42	9.42 $\pm$ 3.06 dBA	9.42 $\pm$ 3.84 dBA
Std. Dev.	5.57		
ISO Mode - Mean	10.19	10.19 $\pm$ 2.14 dBA	10.19 $\pm$ 2.59 dBA
Std. Dev.	4.11		

Considering the position of the error ellipse, Figure 4, this poor attenuation could have been expected. This is proof that the error ellipse provides good results from short and quick measurements (Appendix A). The painstaking procedure of measuring attenuation with dosimeters is not necessary if clamping force versus head size are evaluated. Controlling clamping force; controlling the wear and tear on ear muffs; and maintaining or replacing outright those muffs that have begun to show signs of deterioration (visible or invisible) are necessary for good attenuation control.

MARK IV MUFFS

An even poorer attenuation, and a large standard deviation (due to the small population), was achieved by the Mark IV, MSA ear muffs:

Characteristic	dBA	90% Conf. Limit	95% Conf. Limit
OSHA mode - Mean	8.39	9.42 ± 3.06 dBA	9.42 ± 3.84 dBA
Std. Dev.	6.99		
ISO mode - Mean	8.20	10.19 ± 2.14 dBA	10.19 ± 2.59 dBA
Std. Dev.	6.39		

Confidence in results is low because only nine measurements were taken. With the other two types of ear muffs, Peltor H7P3e and Bilsom Viking 2314, measurements were not evaluated.

EAR MUFF COMFORT

Overall, ear muff comfort was deemed good by the workers (Table 4). "NO NOISE" ear muffs had poor attenuation, but they were judged positively for comfort.

Table 4 - Comfort of ear muffs in mines and mills

No.	Ear Muff	N*	○ -Satisfactory		◒ -Good		● -Very good	
			N	Percent	N	Percent	N	Percent
1	"NO NOISE" (NN3-F)	23	7	30.4	15	65.2	1	4.3
2	Mark IV, MSA	9	2	22.2	7	77.8	0	0.0
3	Peltor H7P3e	9	2	22.2	7	77.8	0	0.0
4	Viking muff No.2314, Bilsom	5	0	0.0	4	80.0	1	20.0
1-4		46	11	23.9	33	71.7	2	4.5

Note: * Population ($N^* = N + N + N$)

Seventy per cent of the employees thought comfort was good or better, while 30% were only satisfied. If we consider this result against the area covered by the error ellipse in Figure 4, we can see that only 20% of the ellipse

area covers the field of ear muff clamping force. Comfort and clamping force have diametrically opposing results of almost equal magnitude:

"NO NOISE" Ear Muffs	Comfort	O-Satisfactory 30.4%	⊖-Good 68.5%
	Area of error ellipse	Non-coverage 80.0%	Coverage 20.0%

It becomes clear why attenuation is poor (≈10 dBA), and that the problem lies in clamping force efficiency.

From field work observations, surveyors found that safety glasses are uncomfortable and sometimes painful when worn with ear muffs.

CONCLUSIONS

Measurements performed at Falconbridge Mine have shown that the efficiency of "NO NOISE" ear muffs is poor, and that their attenuation at this mine is no more than 10 dBA. Many variables affect the "real world" attenuation of ear muffs at this mine:

- type of muffs (helmet or head band);
- condition of muffs (hard or flat cushion, torn seal, bent arms, etc.);
- fitting of muffs (seated correctly, or incorrectly);
- physical considerations (shape and size of head, size of ears);
- job functions (required amount of head turning); and
- physical obstructions (eye glasses - some thicker wands, larger gap, cause discomfort also).

The jackleg drill still gives off more than 105 dBA after attenuation by ear muffs. Ear plugs are not capable of reducing noise by a further 15 dBA to reduce the noise to the 90 dBA level. Ear muff control should be continued by measuring head size and clamping force with the apparatus suggested in the main report.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the help and cooperation of E. Isaacs, Director, and P. Savalas, Field Technical staffe of M.A.P.A.O., as well as L.H. Rajala and N.A. Girard, Senior Mine Supervisors, Dr. A.G. Cecutti, Medical Director, D. McPhee and R. Desjardins, Technicians, and J. Dwyer, Safety Dept. of Falconbridge Ltd.

Acknowledgement is also extended to J. Vergunst, Working Environment Engineer, Ontario Ministry of Labour, Sudbury, and R. Pleasance, Manager, Levitt-Safety Ltd., (Metrosonics Inc.), Sudbury for the loan of the instruments.

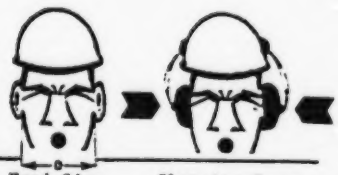
Thanks are extended to G. Knight, Research Scientist, Elliot Lake Laboratory for reviewing this manuscript and making numerous helpful suggestions.

REFERENCES

1. Perce, F., "Noise: industry turns a deaf ear"; New Scientist, No. 1485, December 1985.

2. Bruel, P.V., "Do we measure damaging noise correctly"; Technical Review No. 1, Bruel and Kjaer, Copenhagen, Naerum, 1976.

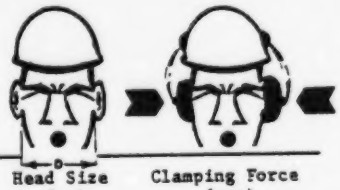
Head size and clamping force data of "NO NOISE", model NN3-F ear muffs



No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	2	14.75	1300
2	Driller	1	14.00	900
3	Driller	3	14.00	850
4	Driller	3	14.50	1000
5	Driller	1	15.00	1200
6	Driller	1	13.00	850
7	Driller	1	14.75	400
8	Raise Driller	2	13.50	1000
9	Raise Driller	1	13.00	400
10	Trammer	2	14.25	1200
11	Trammer	1	14.00	1750
12	Trammer	1	14.00	1500
13	Trackman	2	13.75	1650
14	Trackman	1	14.00	1175
15	Conveyor Operator	1	14.00	1200
16	Motorman	1	14.75	1000
17	Deckman	1	14.50	950
18	Mechanic - Heavy Equipt.	1	14.00	1300
19	Crusherman	1	15.50	1300
20	Stope Boss	2	13.75	400
21	Stope Boss	3	14.00	600
22	Stope Boss	1	13.50	900
23	Stope Boss	2	14.50	750
24	Stope Boss	2	13.50	950
25	Stope Boss	1	14.25	775
26	Stope Boss	1	14.00	700
27	Shift Boss	1	14.25	1100
28	Shift Boss	1	14.25	1000
29	Geology	1	14.00	1100
30	Engineering	1	14.00	1300
31	Ventilation Man	2	14.00	775
32	Ventilation Man	1	13.25	700
33	Ventilation Man	1	14.00	800
34	Ventilation Man	1	14.25	1100
	Mean:		14.14	990.44
	Std. Dev.:		0.54	322.22

Note: 1 - Good; 2 - Fair; 3 - Poor.

Head size and clamping force data of different muffs: MSA Mark IV; MSA Mark V Ear Cup Kit; Peltor H7P3e; and Bilsom Viking muff 2314



MARK IV MUFFS

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	2	12.50	500
2	Driller	2	14.00	1400
3	Driller	2	13.50	600
4	Driller	3	13.50	700
5	Stope Boss	2	13.50	900
6	Stope Boss	2	14.25	1050
7	Level Cleaner	1	13.75	975
8	Ventilation Man	1	13.50	1175
9	Noise Analyst	2	13.75	1200
10	Noise Analyst	2	14.25	1300
	Mean:		13.65	980
	Std. Dev.:		0.50	303.65

MARK V MUFFS

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Stope Boss	1	14.00	950
2	Trammer	1	14.00	1200
3	Crusherman	1	14.25	1100
4	Carpenter Foreman	1	14.25	1300
5	Noise Analyst	1	13.75	1200
6	Noise Analyst	1	14.00	1275
	Mean:		14.04	1170.83
	Std. Dev.:		0.19	128.86

PELTOR MUFFS (H7)

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Noise Analyst	1	14.00	1300
2	Noise Analyst	1	13.75	1175

BILSOM MUFF (2314)

No.	Occupation	Condition	Head Size (cm)	Clamping Force (gwt)
1	Driller	2	13.50	1350
$\bar{x}$	Mean:		14.01	1025.00
	Std. Dev.:		0.53	301.00

Note: 1 - Good; 2 - Fair; 3 - Poor.

Attenuation tests of "NO NOISE" model NN3-F, the Hellberg Standard Volume Hearing Protector, in OSHA and ISO modes

No.	Equipment	Comfort		L_{OSHA} (dBA)	OSHA Attenuation (dBA)			L_{eq} (60s) (dBA)	ISO Attenuation (dBA)			dBA			Comments	Location
					L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	Slow	Fast	Peak		
1	Jack Leg Drill (D. Tymchuck)	◒	14.5	98.7	>20	>17.3	>18.7	111.2	-	-	-	-	-	-	Drilling completed too fast. SIM readings appear low.	No. 5 shaft, 4500 level, 4447 stope.
2	Jack Leg Drill (M. Rheault)	◒	14.5	>114.6	>14.3	14.5	14.4	117.4	17.7	15.63	16.66	117	117.5	132.2	Two drills operating in close quarters.	No. 9 shaft, 4500 level, 4447 undercut.
3	Jack Leg Drill (R. Durette)	◒	13.0	>115	>5.9	>9.6	>7.8	115.4	14.4	0.45	7.43	116.8	117.5	131.5		No. 5 shaft, 500 level, 4650 undercut.
4	Jack Leg Drill (A. Legault)	◒	13.75	>115	>15.5	>6.6	>11.1	116.1	4.8	8.8	6.8	115.8	116.0	131.7		No. 5 shaft, 500 level, 4650 undercut.
5	Jack Leg Drill (G. Robichaud)	◒	13.0	114.2	16.3	18.6	17.5	116.8	22.9	8.9	15.9	117.7	117.1	131.5		No. 5 shaft, 1900 level, 5268 No. 2 hole undercut.
6	Stoper Drill - Rock Bolting (S. Smith)	○	14.0	105.5	4.3	0.8	2.6	100.0	-	-	-	85.3	93.7	109.7	Ear muff arms intentionally bent; "too much vibration". Wears plugs and muff; ISO - malfunction.	5300 level, East Mine.
7	Jumbo Drill (two boom) (C. Plante)	◒	14.25	109.5	10.3	10.1	10.2	110.0	18.3	2.3	10.3	110.7	110.6	123.6		No. 9 shaft, 4300 level, 4152 stope.
8	"Long Tom Drill" (two Booms) (B. Smith)	○	14.0	>115.0	-	-	-	118.3	-	-	-	114.3	118.8	130.8	All readings inside and outside muffs were 115 dBA. Dosimeter failed on left side test.	5300 level, East Mine.
9	In the Hole Drill - I.R (A. Demers)	○	14.0	100.9	>21.2	>20.5	>20.9	100.5	11.19	>19.6	>15.39	99.7	99.9	115.3	Normally wears plugs only.	5300 level, East Mine.
10	In the Hole Drill - I.R.H. (V. Foucher)	◒	13.5	92.6	>11.0	>12.1	>12.6	94.5	11.2	17.59	11.89	93	93.3	111.1		5500 level, East Mine.
11	Mucking Machine (G. Gainer)	◒	13.5	107.3	8.9	17.3	13.1	106.5	3.9	10.6	7.25	106.5	109.4	124.4		No. 5 shaft, 300 level, 6698 backs.
12	Slusher (T. Tassier)	◒	12.0	94	0.3	8.3	4.3	96	8.23	3.6	5.92	95.6	96.5	109.7	Poor seal on left ear, very difficult to fit muff.	No. 9 shaft, 4800 level, 5002-4547 undercut.
13	Slusher (R. Weaver)	◒	13.5	99	18.7	12.1	15.4	97.3	13.24	17.0	15.12	96.4	96.9	110.3		No. 5 shaft, 1900 level, 5268, No. 1 hole undercut.

No.	Equipment	Comfort	L_{OSHA} (dBA)	OSHA Attenuation (dBA)			L_{eq} (60s) (dBA)	ISO Attenuation (dBA)			dBA			Comments	Location
				L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	Slow	Fast	Peak		
14	Scooptram - Wagner	○	11.5	105.5	3.1	0.2	1.7	100.4	-	-	-	103	103.5	120.7	RACAL Airstream Helmet may limit clamping force, especially on this small head. ISO malfunction.	3500 level, East Mine, No. 25 draw point.
15	Scooptram - Jarco (B. Millar)	○	14	94.7	4.3	>17.1	>10.7	92.8	3.83	9.17	6.6	94.2	93.5	108.3		No. 9 shaft, 4300 level, 4152 stope.
16	Primary Crusher, 4100 Level (P. Lalonde)	○	14.5	96.9	>16.2	>17.6	>16.9	95.2	>27.3	>26.9	>27.1	94.7	94.9	114.2	Mr. Lalonde finds ear plugs better than "muffs".	No. 5 shaft, 4100 level, crusher.
17	Primary Crusher, 6100 Level (P. Lalonde)	○	14.5	106.9	4.0	10.8	7.4	104.5	10.5	1.0	5.75	104.8	104.8	117.8	Very heavy vibration area due to vibrating pass feeding.	No. 5 shaft, 6100 level, crusher.
18	Tertiary Crushers - Operating Floor (R. Cruikshank)	●	14	95.9	1.8	13.3	7.6	94.9	3.64	>14.5	>9.07	95.4	95.6	107.9	Worker borrowed muff, normally wears plugs only.	Fine crushing plant.
19	Tertiary Crushers - Operating Floor (P. Savalas)	◒	14.5	100.6	>19.7	>21.5	>15.6	96.6	11.1	14.6	12.61	95.2	95.3	108.8		Fine crushing plant.
20	Ball Mill Operator Area (P. Savalas)	◒	14.5	88.7	>10	>8.3	>9.2	92.5	11.3	>13.26	>12.28	92.0	91.7	107		Falconbridge Mill.
21	No. 1 Electrostatic Precipator (P. Savalas)	◒	14.5	88.5	>8.1	>8.9	>8.5	94.6	11.93	>12.19	>12.15	89.9	93.4	106.5		Smelter.
22	Converter Punchers (P. Savalas)	◒	14.5	96.2	16.0	>15.4	>15.7	99.1	>19.76	15.19	>17.47	100.3	100.4	115.8	Majority of time behind punchers - not normally for this occupation.	Smelter.
23	No. 7 (Converter Skimmer - Fluxing (P. Savalas)	◒	14.5	85.8	-	>4.9	-	86.6	>3.66	>2.4	>1.03	84.5	86.0	102.4		Smelter.
	Mean		13.71	99.02	8.0	10.6	9.42	102.49	11.14	9.23	10.19	101.04	102.10	116.87		
	Std. Dev.		0.84	7.67	6.47	6.18	5.57	9.51	5.53	5.80	4.11	10.50	10.18	9.80		

Note: ○ Satisfactory; ◒ Good; ● Very good. Undetermined numbers (> No.) are not in Mean value.

Attenuation tests of Mark IV, MSA ear muffs, in OSHA and ISO modes

No.	Equipment	Comfort		L_{OSHA} (dBA)	OSHA Attenuation (dBA)			L_{eq} (60s) (dBA)	ISO Attenuation (dBA)			dBA			Comments	Location
					L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	Slow	Fast	Peak		
1	Jack Leg Drill (A. Schock)	-	13.5	>115	-	-	-	106.5	-	-	-	119.7	118.3	131.3	Ear muff cushions very hard. Cups full of water, Mal-function.	2900 Level - East Mine 3102-3133 undercut.
2	Jack Leg Drill (G. Kaiser)	◒	13.5	>110.1	>30	>25.4	>27.7	116.1	-	>39	-	115.9	115.6	132.2	Mark V. Dosimeters were taken out of operation.	No. 5 shaft, 3500 level.
3	Jack Leg Drill (A. Poropat)	●	14	114.3	2.6	5.8	4	116.7	1.2	7.6	4.4	118.5	117.3	131.8	Drilling in progress nearby.	No. 9 shaft, 4800 level 5002-4547 undercut.
4	Jumbo Drill (Two Boom) (A. McGuire)	●	13.5	106.8	5.4	11.3	8.4	111.1	8.47	5.87	7.17	111.2	113.3	125.6	"Too noisy, especially when glasses worn".	No. 5 shaft, 2900 level
5	Mucking Machine (M. Charette)	◒	14.25	107	0.6	2.7	1.65	105	2.59	2.54	2.56	102.5	102.3	116.8	Plugs and muffs worn. "Muffs alone too noisy".	5300 Level, East Mine.
6	Mucking Machine (L. Lachance)	◒	13.5	105.6	12.2	13.1	12.7	106.5	14.8	>12.7	>13.75	110	109.7	124.2		No. 5 shaft, 300 level 6698 Sacks
7	Mucking Machine (A. Poropat)	●	14	103.1	5.0	1.6	3.3	104.6	10.0	2.5	6.25	104.8	104.9	120.7		No. 9 shaft, 4900 Level undercut.
8	Slusher - Joe (L. Lachance)	◒	13.5	-	-	7.5	-	91.2	6.7	9.8	8.25	91.8	92.3	107.6	Dosimeters failed - No test on left side.	No. 5 shaft, 300 level
9	Slusher (H.G. Kollsnek)	○	14.75	105.5	13.0	27.1	20.1	100.5	20.57	21.14	20.57	103.8	104.3	117.8	Large head. > Apparent attenuation.	No. 5 shaft, 300 level 4650 undercut and fill.
	Mean		13.83	107.05	6.47	9.87	8.39	107.58	9.11	8.24	8.20	108.69	108.67	123.11		
	Std. Dev.		0.45	3.81	5.06	8.67	6.99	8.54	6.62	6.93	6.39	8.94	8.51	8.27		

Note: ○ Satisfactory, ◒ Good, ● Very good

Undetermined numbers (> No.) are not in Mean value.

Attenuation tests of Peltor (H7P3e) ear muffs, in OSHA and ISO modes

No.	Equipment	Comfort		L_{OSHA} (dBA)	OSHA Attenuation (dBA)			L_{eq} (60d) (dBA)	ISO Attenuation (dBA)			dBA			Comments	Location
					L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	Slow	Fast	Peak		
1	Compressor Room (D. Jobin)	◒	14	R.S. (89.3)	-	>9.3	-	91.9	>11.4	>4.9	8.15	90.3	89.7	103	Head band, prefers these muffs to plugs or no noise muffs.	No. 5 shaft, compressor boiler house.
2	Secondary Crusher - Belt Picker (H. Felske)	○	14.75	92.6	10.1	>12.2	>11.2	92.9	2.56	5.34	3.95	93	93.3	108	Head band. This man had no hearing protection at all.	No. 5 shaft, Rock house.
3	Secondary Crusher - Belt Picker (H. Felske)	○	14.75	93.6	6.7	0.3	3.5	90.9	0.13	4.8	2.47	90.6	90.9	104.8	Head band. Very large ears. Poor fit on right side as ear was showing.	No. 5, Rock house.
4	Secondary Crusher - Belt Picker (R. Hull)	◒	13	87.2	3.1	>5.8	>4.5	90.1	>10.6	10.7	>10.64	90.1	91.1	106	Head band. This man had no hearing protection at all.	No. 5, Rock house.
5	Ball Mill Operator (D. Jobin)	◒	14	88.9	>8.5	>9.3	>8.9	92.3	12.26	>12.2	12.2	92.9	92.4	106.8	Ball mill operator wears plugs only.	Mill
6	Power House (L. Tiessen)	◒	14	98.7	>17.2	>20.2	>18.7	94.0	>14.1	>15.2	>14.65	94.9	94.5	107.5	Outside control room "Very pleased with these muffs".	No. 2, Power house.
7	Converter Skimmer - Fluxing (R. Hull)	◒	14.28	82.5	-	>4.9	-	97.4	21.6	>19.3	>20.45	94.9	94.9	109.3	"Will not work without his muffs".	Smelter. No. 7 Converter
8	Converter Puncher (D. McPhee)	◒	14	97.9	>17.5	>18.2	>17.9	98.3	>16.5	>16.2	>16.3	98.8	98.6	112.3		Smelter No. 7 Converter
9	Electrostic Precipitator (D. McPhee)	◒	14	91.4	>9.3	>13.5	>11.4	98.0	11.8	>14.0	>12.9	95.3	93.9	111.9		Smelter No. 1 Electrost. Prec.
	Mean		14.00	93.98	-	-	-	93.5	9.67	6.95	-	93.42	93.26	107.7%		
	Std. Dev.		0.52	3.15	-	-	-	3.6	8.58	3.25	-	2.87	2.66	3.08		

Note: ○ Satisfactory, ◒ Good, ● Very good

Undetermined numbers (> No.) are not in Mean value.

Attenuation tests of the Bilsom Viking muff 2314

No.	Equipment	Comfort		L_{OSHA} (dBA)	OSHA Attenuation (dBA)			L_{eq} (60s) (dBA)	ISO Attenuation (dBA)			dBA			Comments	Location
					L.S.	R.S.	B.S.		L.S.	R.S.	B.S.	Slow	Fast	Peak		
1	Scooptram JS221 (G. Boulard)	●	14	96.2	30.1	>16.2	>23.2	100.5	8.3	15.4	6.85	103.8	104.3	117.8	Comfort (2314). "Very pleased with these muffs". Covers ears well.	No. 9 shaft, 4300 level. No. 152 stope.
2	Ball Mill Operator Area (D. McPhee)	◒	14	87.8	>7.7	>7.8	>7.8	94	>8.2	14.8	>11.5	94.4	95.5	108.9		Mill.
3	Flotation Operator Area (D. McPhee)	◒	14	-	-	-	-	88.4	>7.09	>12.7	>9.89	87.6	85.9	99.3	Invalid test. Dosimeter malfunction.	Mill.
4	Converter Skimming - Fluxing (D. McPhee)	◒	14	87.9	>6.3	8.3	>7.3	88.9	>13.5	4.07	>8.78	85.2	87.5	99.8		Smelter.
5	Converter Punchers (D. McPhee)	◒	14	97.6	>17.6	>17.5	>17.6	99.3	>16.3	>6.13	>12.2	98.4	98.4	114.7		Smelter.
	Mean		14	92.38	-	-	-	94.22	-	-	-	93.88	94.32	108.1		
	Std. Dev.		-	5.26	-	-	-	5.65	-	-	-	7.65	7.67	8.44		

Note: ○ Satisfactory, ◒ Good, ● Very good

Undetermined numbers (> No.) are not in Mean value.

Appendix G

L(MAX) AND L(PEAK) LEVELS

Using Appendices A to F, measurement results were calculated for L(max) and L(peak) levels (Table G-1). The aim was to see how big the "peaks" are, which according to some authorities, influence loss of hearing (2). Measurements were made with an integrating sound level meter, B and K, type 2225. Instrument control was performed to find means of standard deviation for L(max) and L(peak). Results were approximately the same. This method of control is used during field measurements. The confidence limits of results were:

90% Confidence Limit		95% Confidence Limit	
L(max)	L(peak)	L(max)	L(peak)
3.16 to 5.86 dBA	3.81 to 6.19 dBA	2.85 to 6.17 dBA	2.60 to 7.4 dBA

From this information we can see how precise the measurements were.

Table G-1 - Peak levels in mining, milling and smelting operations at Falconbridge and Strathcona mines.

Falconbridge - Strathcona

Instrument: Bruel and Kjaer Integrating Sound Level Meter Type 2225.

No.	Sound Source	dBA L_{max} Mean Std. Dev.	dBA L_{peak} Mean Std. Dev.	Δ	N
1	Jack Leg Drill	118.65 3.36	134.85 5.68	16.3	11
2	Stoper Drill - Rock Bolter	118.51 5.92	135.0 7.0	16.5	22
3	Jumbo Drill - two booms	116.96 5.91	122.14 5.91	15.19	8
4	Long Hole Drill	119.19 1.98	135.08 2.59	15.89	4
5	Long Tom Drill - two booms	120.27 2.99	137.17 4.63	16.9	23
6	ITH In the Hole Drill	98.27 5.12	116.25 5.66	17.98	7
7	Diamond Drill	104.02 4.76	120.81 9.93	16.79	7
8	Mucking Machine	106.58 3.60	121.53 3.53	14.95	4
9	Bolting Machine	-	-	-	-
10	Air Plugger (Brk. Cement)	-	-	-	-
11	Slusher	97.50 4.99	111.35 4.45	13.85	4
12	Scooptram	106.55 14.57	123.33 11.80	16.78	12
13	Conveyor Man	94.83 6.40	112.15 8.35	17.32	3
14	Chute Puller	114.80 9.19	133.15 3.32	18.35	2
15	Vent. Fan - 38" 60 HP	-	-	-	-
16	Primary Crusher - U/G Jaw Crush.	102.34 6.93	121.56 8.24	19.22	8
17	Secondary Crusher	91.77 1.33	106.27 1.62	14.5	3
18	Tertiary Crusher	95.45 0.21	108.35 0.64	12.9	2
19	Ball Mill	93.20 2.02	107.57 1.16	14.37	3
20	Flotation Op. Area	85.9	99.3	13.4	1
21	Compressor Room	89.7	103.0	13.3	1
22	Power House	94.5	107.5	13.0	1
23	Electrostatic Precipitator	93.65 0.35	109.20 3.82	15.55	2
24	Converter Puncher	99.13 1.10	114.27 1.79	15.14	3
25	Converter Skimmer - Fluxing	89.47 4.76	103.83 4.91	14.36	3
		Mean$_{SD}$ Std.Dev.	Mean$_{SD}$ Std.Dev.		
		4.51	5.00		
◇ 19		3.45	3.04	19 ◇	